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Citation for published version (APA):
Brom, H. B., Kramer, G. J., Berg, van den, J., & Jol, J. C. (1988). Similarity between the Co(2)-O-planes in tetragonal and orthorhombic YBa2Cu3O7-delta as probed by 89Y NMR. *Physica C : Superconductivity*, *153-155*(Pt. 2), 735-736. https://doi.org/10.1016/S0921-4534(88)80062-5

DOI:
10.1016/S0921-4534(88)80062-5

Document status and date:
Published: 01/01/1988

Document Version:
Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:

• A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
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Physica C 153–155 (1988) 735–736
North-Holland, Amsterdam

SIMILARITY BETWEEN THE Cu(2)-O-PLANES IN TETRAGONAL AND ORTHORHOMBIC $YBa_2Cu_3O_{7-\delta}$ AS PROBED BY ^{89}Y NMR

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^{89}Y-NMR linewidth and relaxation rate data are reported for $YBa_2Cu_3O_{7-\delta}$ in the orthorhombic metallic and the tetragonal nonmetallic modifications.
The temperature dependence of the observed relaxation rates is Korringa like with almost equal Korringa constants for both compounds. These results are correlated to the Cu(2) NMR data of Warren et al. and might be seen as a support of any theory which decouples charge transport from spin fluctuations.

1. INTRODUCTION

We will present data on ^{89}Y nuclear spin lattice relaxation rates in $YBa_2Cu_3O_7$, YBCO, both in the 90 K superconductor as well as in its tetragonal modification. In previous ^{89}Y-NMR studies in orthorhombic YBaCuO, O-YBCO, (1,2) both the temperature dependence of the nuclear relaxation rate (T_{1n}^{-1}) and the observed lineshift were interpreted in terms of a Korringa mechanism. The increased linewidth below T_c (1) was explained in terms of field gradients caused by vortex formation, while the line splitting observed already above T_c (2) was connected to a charge redistribution in the nearby Cu(2)-O plane. Both the Y relaxation and line broadening are dominated by the Cu-Y electronic spin - nuclear spin interaction, and similar relaxation behaviour for the Y and Cu(2) nuclei has been observed (3).

2. METHOD AND MATERIAL

The samples used were prepared as described by van den Berg et al. (4). The O-YBCO had a transition temperature of 90 K with a susceptibility width of 2 K, while no superconductivity was observed in the tetragonal sample, T-YBCO. For the NMR measurements the particles were sealed to prevent deterioration due to contact with water vapour and results were reproducible during the duration of the experiment.

Relaxation times were measured at 9.8 MHz by using a comb of $\pi/2$ pulses followed by a reading pulse of $\pi/2$. A delay time of 200 - 300 μs was allowed to suppress the effect of "electronic noise" in the signal without too severe loss of sensitivity ($T_2 \sim 1$ ms). A flow cryostat provided the variable temperatures, which were measured with a Pt-resistor and a Au-chromel thermocouple.

Our results for the relaxation time in O-YBCO and T-YBCO are given in figure 1 together with the data points of Markert (1).

3. DISCUSSION

In discussing the T_{1n}-data the similarity of the Y-data in both modifications of the YBCO compound is the most prominent feature. It has to be realized that the earlier given interpretation in terms of a Korringa process was straightforward in view of the dc electrical resistivity of about 5×10^{-4} Ω cm, as measured in the ab plane (5), a factor of 25 × lower than that for YH_2: the low Korringa constant agrees with that. For that reason the data in T-YBCO are a surprise, the electrical resistivity being a factor of 10^4 higher than for O-YBCO (6).

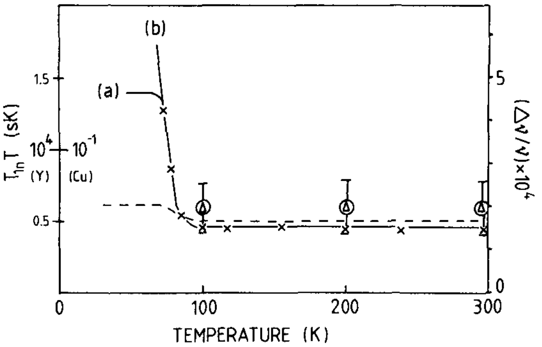

FIGURE 1

The product of the ^{89}Y relaxation time (T_{1n}) and temperature (T) vs T. The crosses indicate the result of Markert et al. (1) in O-YBCO, triangles are our results for T-YBCO. In the same figure the line shift, normalized on the "free" Y-larmor frequency is given (circles), the scale is on the right. The extrapolation (b) is given by Markert et al. (1); (a) is the alternative proposed in this paper. The dashed line represents the Cu(2) NMR data of Warren et al. (3); the corresponding units are given on the left side of the figure.

0921–4534/88/$03.50 © Elsevier Science Publishers B.V.
(North-Holland Physics Publishing Division)

If we restrict ourselves for the moment to an interpretation in terms of a normal Korringa process, there are a few indications that the required electron density for such a process is indeed possible. In the low temperature specific heat data, as measured e.g. by von Molnar et al. (7) a linear term, i.e. $C = \gamma T$, is present which is similar for both O-YBCO and T-YBCO. Furthermore the Cu(2)-NMR data (3) show a large relaxation rate at 4.2 K. Assuming a Korringa-like instead of a temperature independent T_{1n}-behaviour, as suggested by Warren et al. (3), a second indication for "metal like" electrons is present. The change in the Korringa constant at T_c might well be associated with an electronic rearrangement in the Cu(2)-O basal plane by e.g. the partial development of a CDW or SDW.

[There is a discrepancy of the Cu(2) data and the Y data of Markert et al. (1) we like to comment on. From the scaling between the Y and Cu(2) data and the above mentioned change in Korringa constant at T_c a possibly (much) larger change might happen for the Y nuclei (interpreted previously as the opening of gap (1)). A continuation of the Y and Cu(2) scaling with a (much) larger scaling factor is then expected].

Also the increase of $(T_{1n}T)^{-1}$ at the lowest temperature (3) is not unusual in low dimensional systems.

In this way, the usual interpretation of the Korringa relation in the presence of s-state conduction electrons, together with the assumption of an electronic origin of the γT-term in the specific heat, leads to a picture of localized (in T-YBCO) or delocalized (in O-YBCO) electrons.

The above given picture is based on the usual interpretation of the Korringa relation in terms of conduction electrons. The basis of the connection between nuclear relaxation rate and line shift is however not the presence of charges but the presence of spins with Fermi-Dirac statistics (9) having interacting with the nuclear spins. Therefore the absence of a correlation between charge transport and nuclear relaxation rate can be seen as a strong support for those models that decouple charge transport and spin dynamics and especially that assign to the spins a (pseudo) Fermi surface. It is in the Resonant-Valence-Bond-model (10) that this is done explicitly: the spinons seem to be capable of giving the required relaxation process without directly leading to charge transport.

At the end we briefly like to comment on the possible influence of impurities and structural differences between T-YBCO and O-YBCO.

The larger lattice constant in T-YBCO than in O-YBCO arises because oxygen contracts the lattice in its surrounding i.e. primarily it is the Cu(1)-surrounding which is involved and the changes will not be relevant for the Y sites.

Localized impurities will relax nearby Y or Cu-nuclei while other similar nuclei will reach thermal equilibrium via spin diffusion. Depending on concentration, diffusion barrier etc. quite a number of cases have to be considered, none of which is expected to give a linear T dependence around room temperature. The strongest argument against the impurity model is the unique shift (combined with the narrow NMR line) of the Y-nuclei, which indicates the same spin density for all nuclear sites.

4. CONCLUSION

The identical ^{89}Y-relaxation rates in O-YBCO and T-YBCO can be understood from the unchanged character of the nearby Cu(2)O-plane and are strong evidence for the decoupling of charge transport and spin fluctuations.

ACKNOWLEDGEMENTS

This work is part of the research program of the Leiden Materials Science Centre (Werkgroep Fundamenteel Materialen Onderzoek) and is supported by the "Stichting FOM" (Foundation for Fundamental Research on Matter) which is sponsored by ZWO (Netherlands Organization for the Advancement of Pure Research).

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